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FLAVOR AND STORAGE STABILITY OF EXPLOSION-PUFFED POTATOES: AUTOXIDATION

ABSTRACT

The principal cause of off-flavor in explosion-puffed, air-packed potato dice at 23°C is autoxidation. A butylated hydroxyanisole/butylated hydroxytoluene system applied to the dice retarded autoxidation and samples were stored successfully for 12 months. The standard (nitrogen-pack, 23°C) was not significantly different from samples stored at −18°C. A trained taste panel found significant deterioration in air-packed samples, without antioxidant, after 3 months. Gas-liquid chromatographic analysis of the headspace in all samples allowed the monitoring of n-hexanal. Relative concentrations of this compound correlated highly with flavor degradation. Explosion-puffed potato dice showed similar storage stability when packaged in oxygen scavenger pouches or in nitrogen. Pouches, however, showed susceptibility to pinhole leaks.

INTRODUCTION

UNWANTED FLAVORS in explosion-puffed dehydrated potatoes have been attributed to two phenomena: nonenzymatic browning and autoxidation. These can be further categorized as either processing or storage off-flavors.

Flavor deterioration during the explosion-puffing step is due primarily to nonenzymatic browning. In the puffing gun, potatoes at 30% moisture (wet basis) are subjected to temperature conditions conducive to nonenzymatic browning which results in the formation of volatile aldehydes among other products. The high-temperature conditions are a result of the pressurized superheated steam operation which is an integral part of the explosion-puffing process (Turkot et al., 1966). A means of inhibiting off-flavor contributing aldehydes formed during processing had to be developed prior to considering flavor degradation in storage. Cording and Sullivan (1973) discovered that dilution of the superheated steam with nitrogen was an effective method of retarding nonenzymatic browning during puffing. Browning of low-sugar potatoes (total reducing sugars less than 2%) puffed in a nitrogen/steam mixture and stored at room temperature was found to be insignificant over a 12-month storage period (Sullivan et al., 1974).

The dominant off-flavor that develops during the storage of dried potato products is due to the autoxidation of the potato lipids. When potato products are air-packed the flavor quality drops rapidly. Buttery et al. (1961) related this off-flavor development in air-packed potato granules stored at 24°C to the oxygen absorption and the degree of autoxidation of linolenic and linoleic acids. Hexanal is a major volatile product of the autoxidation of potato lipids and is one of a number of compounds responsible for the rancid off-flavor in potato products. The amount of hexanal in stored potato products is considered to be an accurate index of autoxidation (Boggs et al., 1964).

This paper describes tests for determining the effectiveness of three methods of retarding autoxidation: (1) packaging in a nitrogen atmosphere; (2) packaging in a H_2-palladium catalyst, oxygen scavenger pouch; and (3) adding antioxidants at some point during processing. This latter method permits the use of packaging in an air atmosphere.

EXPERIMENTAL

Raw material preparation

Low sugar Maine Kennebec potatoes were used for all studies. The potatoes were submerged in a 20% (by weight) caustic solution to loosen the skins, which then were removed with high pressure water jets. After being trimmed, the potatoes were dipped in a solution of 1/2% sodium bisulfite, 1/2% citric acid to prevent enzymatic browning. This dip was repeated each time a new potato surface was exposed. The potatoes were then cut into nominal 1 cm cubes and passed over a 0.5 cm mesh shaker screen to eliminate slivers and fines, which dry much faster. The dice were washed to remove surface starch, precooked for 15 min at 71°C, cooled for 10 min in water (<21°C) (Cording et al., 1955, 1959) and blanched for 15 min in atmospheric steam. A final dip in a 1/4% $NaHSO_3$, 1/4% Na_2SO_3 solution for 1 min was employed to control nonenzymatic browning during the drying cycle. The potato dice were dried to 25–30% moisture (wet basis) in a batch, through flow air drier at 93°C for approximately 2 hr. After equilibration for 18–24 hr to insure a more uniform moisture distribution within and among dice, they were coated with sodium silico aluminate (1.25% by weight solids) to prevent sticking.

Antioxidants were applied as an ethanol solution and were sprayed on using nitrogen as the atomizing agent. Just prior to being explosion-puffed, 6.8 kg of potato dice, spread evenly in a 106 × 65 cm stainless steel tray, were sprayed uniformly with approximately 25% of the solution and then were tumbled thoroughly. The procedure was repeated three times in an effort to achieve a uniform antioxidant application. The amount of the antioxidant in the spray was approximately five times greater than the residue sought since appreciable loss of antioxidant took place during the spraying operation and during the explosion-puffing step.

After being batch explosion-puffed in a 2:1 superheated steam/nitrogen mixture, the dice were dried at 66°C dry bulb to approximately 5% moisture.

Packaging and storage

Samples without antioxidants were packed under nitrogen in 211 × 414 cans or in laminated scavenger pouches. Both packages contained less than 2% oxygen.

The potato dice packaged under nitrogen were used as control samples and were stored at −18°C, 23°C and 38°C with the latter being used for the high temperature study. The potatoes packaged in scavenger pouches and those treated with antioxidant were stored at 23°C and 38°C. (Antioxidant samples were canned in air.) Four antioxidant systems were evaluated in this study. These included butylated hydroxyanisole (BHA) which was first tested as the sole antioxidant, and three mixtures incorporating butylated hydroxytoluene (BHT), propyl gallate (PG), and ascorbyl palmitate (AP) which were added with the BHA to determine if the mixtures would be more effective in retarding autoxidation than BHA alone.

Analytical

BHA was determined by the method of Filipic and Ogg (1960). Total antioxidant was calculated based on the BHA determinations and the known proportions of PG and BHT in the solution when applied. Concentrations of AP in potato extract were extimated by a colorimetric method based on a reaction of the ascorbyl radical with 2,6-dichlor-oindophenol (Loeffler and Ponting, 1942).

Headspace gases in nonair-pack containers were analyzed for oxygen content using a Beckman Model E-2 oxygen analyzer. Samples with oxygen content greater than 2% were rejected.

Gas-liquid chromatography (GLC) was used to measure volatiles in the headspace vapor above a reconstituted potato product (Sapers et al., 1970). To quantitate the GLC data exactly 44 ppm of an internal standard, ethyl butyrate, was added to the sample prior to analysis.

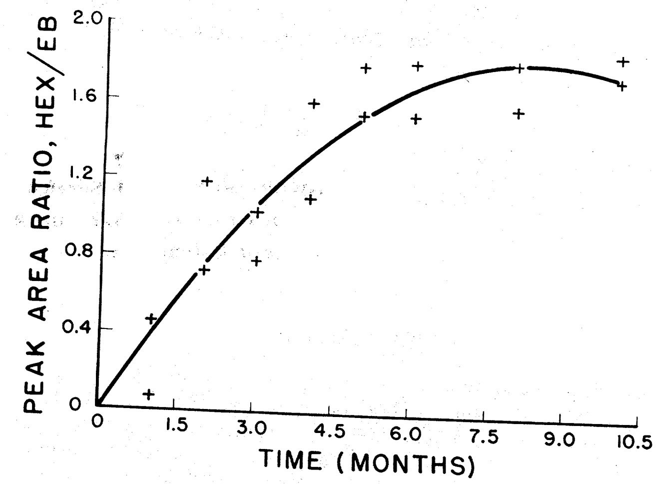

Fig. 1—Hexanal development at 23°C in explosion-puffed potato dice (air pack).

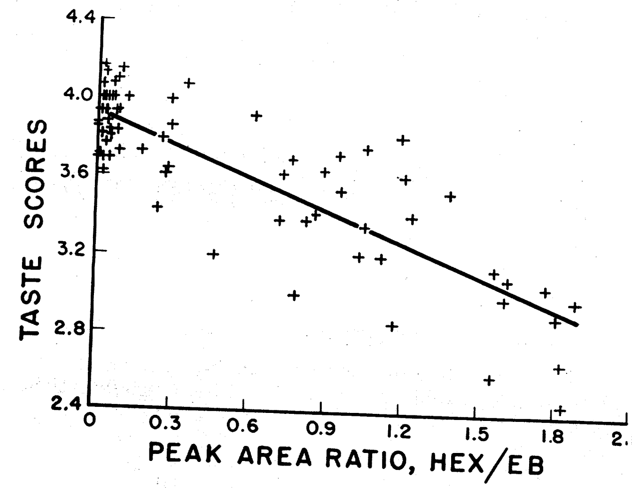

Fig. 2—Correlation of hexanal development and taste of explosion-puffed potato dice.

Each sample was analyzed a minimum of three times and the results are reported as the mean peak area ratio of hexanal to ethyl butyrate (HEX/EB).

Taste evaluations

Sensory evaluations were accomplished by a rating difference test (scalar difference from control) (Prell, 1976; ASTM, 1968) in which the taste of each sample was compared with that of a standard. The exact method followed was that described by Kramer and Twigg (1962). The scoring system provided a range from "1" (very much worse than standard) to "7" (very much better than standard) with a score of "4" indicating that the sample was the same as the standard.

All potato samples were rehydrated in boiling water until soft, then riced to minimize textural differences. The rehydrated product was held on a steam table at 70°C until served to a panel of 15 trained tasters.

Four coded samples and a known control were randomly served in hard, odorless plastic cups to the tasters in a specially designed taste panel room maintained at 21°C and having a positive pressure to exclude extraneous odors. The taste panel booths were lighted with low intensity colored lights and water was supplied for rinsing (Prell, 1976).

The panel was trained by originally selecting 40 persons from within the Center. They were screened for taste acuity by a Triangle test using fresh potato dice and varying amounts of rancid and browned potato dice. About half of this group got over 90% of the Triangle test correct. They were then given scoring tests.

The data thus accumulated were treated statistically by an analysis of variance and a multiple range test at both 95 and 99% confidence intervals (Duncan, 1955). A significant difference between the mean score of a sample and the standard at a 95% confidence level is considered evidence for off-flavor in that sample.

Potatoes were also rated by untrained tasters drawn from a total population of about 300 persons. A minimum of 45 persons were given samples prepared with a bland cream sauce. Each sample was presented as a single stimulus and scored on a standard 9-point hedonic scale (Peryam and Pilgram, 1957).

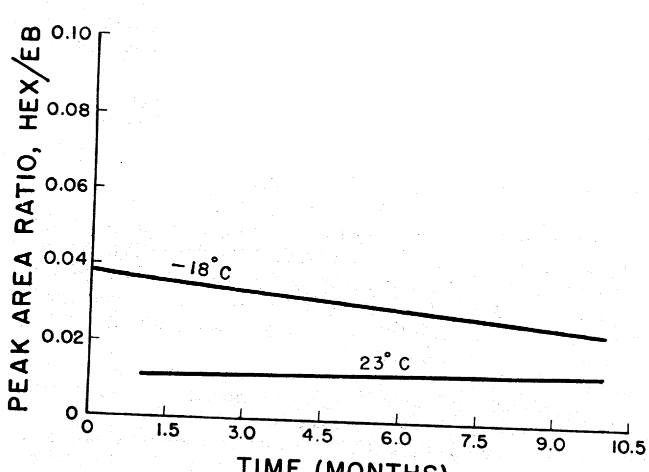

Fig. 3—Stability of explosion-puffed potato dice (N_2 pack).

RESULTS & DISCUSSION

DEHYDRATED POTATO DICE stored in air at room temperature underwent autoxidation and exhibited a corresponding increase in off-flavor. Figure 1, fit by regression, shows an increase in the peak area ratio HEX/EB in products stored under these conditions. Since the internal standard, ethyl butyrate, has been held constant throughout this study, the increase in the peak area ratio can be attributed only to an increase in the autoxidative compound hexanal. The onset of a rancid, oxidative off-flavor was detected by the trained taste panel in products stored for 3 months. This threshold level is equivalent to a HEX/EB peak area ratio of approximately 1.1. The rise in HEX/EB was accompanied by a corresponding decrease in flavor scores (Fig. 2) which suggests that hexanal formation is an accurate index of oxidative off-flavor. A regression analysis of the peak area ratio HEX/EB to the taste scores resulted in a linear function with a correlation coefficient of −0.839 (82 d.f.). These findings are in accord with those reported by Buttery and Teranishi (1963).

Nitrogen atmosphere storage

Samples stored in nitrogen at −18°C were compared to those stored in nitrogen at 23°C. The peak area ratios HEX/EB were not significantly different between the stored samples, nor did either sample show a significant increase with storage time (Fig. 3).

Antioxidant treatment

All antioxidant systems used are shown in Table 1 with product concentrations indicated in parentheses.

In the initial studies BHA was applied at three concentrations: 35, 50, and 70 ppm (Table 2). BHA is shown to be an effective antioxidant at the three levels of concentration that were studied. Samples treated with the lowest level of BHA exhibited the largest HEX/EB peak area ratios, but organoleptic evaluations indicated that these quantities were below the taste threshold. Protection from autoxidation, as measured by hexanal production, was consistent and apparently successful when BHA was used. An inexplicable off-flavor

Table 1—Antioxidant systems

System	Antioxidant[a] (product conc)[b]
1	BHA (35 ppm)
2	BHA (50 ppm)
3	BHA (70 ppm)
4	BHA (25 ppm) + BHT (25 ppm)
5	BHA (35 ppm) + PG (15 ppm)
6	BHA (35 ppm) + PG (15 ppm) + AP (200 ppm)

[a] BHA = Butylated hydroxyanisole; BHT = Butylated hydroxytoluene PG = Propyl gallate; and AP = Ascorbyl palmitate
[b] All product concentrations on "as is" basis

appeared in the 50 ppm sample at 8 months. This off-flavor has not been identified, but low peak area ratios indicated that the quality loss probably was not oxidative in nature. These indications are substantiated by examination of the confidence range for the HEX/EB peak area ratio (1.1) corresponding to the threshold for oxidative off-flavor. In order to calculate this range, the hexanal formation of 50 samples that had been identified as oxidized were studied. Samples with HEX/EB peak area ratios lower than 0.562 had only a 5% probability of being perceived as having an oxidative off-flavor. Sapers et al. (1975) encountered a similar disagreement between GLC and sensory data in one sample. They attributed it to causes other than oxidation.

The data for samples treated with antioxidant mixtures to examine possible synergistic effects are shown in Table 3. Maintenance of an acceptable potato flavor in samples treated with the BHA, BHT combination was obtained over the 12 month storage life whereas the PG/BHA/AP samples developed detectable rancid off-flavors after 5 months in storage.

Pouch storage

The pouches (American Can Company) used for this study utilized a palladium catalyst embedded in the plastic laminate with a nitrogen-hydrogen gas mixture in the pouch itself. The system acts as an oxygen scavenger when the package is filled and sealed. Potato dice were stored in these pouches at 23°C and were compared with a control sample packed under nitrogen and stored at −18°C (Table 4). This type of packaging was as effective as the nitrogen packed control in maintaining a low level of hexanal and in preventing the concurrent off-flavor development. The duration of these tests, however, was only 7.5–9.0 months because the pouches had taken up oxygen. The cause for this problem was attributed to the packages being punctured by the sharp corners of the dice.

—*Text continued on page 414*

Table 2—BHA level effectiveness

		Months					
		0	3	5	8	10	12
23°C N_2	Hex[a]	0.013	0.044	0.026	0.155	0.170	0.130
	Taste[b]	3.81	3.92	3.85	4.07	3.69	3.83
23°C 35 ppm BHA	Hex[a]	0.078	0.714	0.884	0.816	0.942	X[d]
	Taste[b]	3.94	3.38	3.64	3.38	3.73	X
23°C 50 ppm BHA	Hex[a]	0.005	0.241	0.341	0.364	0.406	0.422
	Taste[b]	3.90	3.28	3.64	3.42[c]	3.25[c]	2.66[c]
23°C 70 ppm BHA	Hex[a]	0.028	0.086	0.086	0.248	0.286	X
	Taste[b]	3.77	4.15	3.73	3.80	3.87	X

[a] Mean peak area ratio = $\frac{\text{Area of hexanal peak}}{\text{Area of internal std peak}}$
[b] Taste scores as per Kramer and Twigg (1962)
[c] Indicates a difference at a confidence level of 95% or greater relative to control at same storage time
[d] X = Data not available

Table 3—Antioxidant mixture effectiveness

		Months					
		0	2	5	6	9	12
N_2	Hex[a]	0.013	0.018	0.021	0.031	0.050	0.083
	Taste[b]	3.81	4.07	4.00	4.09	3.84	3.83
BHA and BHT	Hex[a]	0.009	0.143	0.471	0.436	0.567	0.669
	Taste[b]	3.63	3.93	3.42	3.70	4.00	3.75
BHA and PG	Hex[a]	0.028	0.276	1.047	1.228	DC[d]	DC
	Taste[b]	3.92	3.64	3.36[c]	3.42[c]		
BHA, PG, and AP	Hex[a]	0.032	0.240	1.165	1.226	DC	DC
	Taste[b]	3.83	3.43	2.86[c]	3.42[c]		

[a] Mean peak area ratio = $\frac{\text{Area of hexanal peak}}{\text{Area of internal std peak}}$
[b] Taste scores as per Kramer and Twigg (1962)
[c] Indicates a difference at a confidence level of 95% or greater relative to control at same storage time.
[d] DC = Test discontinued

Table 4—Nitrogen canning vs scavenger pouch effectiveness

			Months					
			0	2	5	7.5	9	12
−18°C, N_2 Can	Test 1	Hex[a]	0.013	0.018	0.021	0.093	0.050	0.083
		Taste[b]	3.81	4.07	4.00	3.78	3.84	3.83
	Test 2	Hex[a]	0.019	0.018	0.056	0.042	0.030	0.027
		Taste[b]	4.09	4.08	4.00	3.93	4.00	4.07
23°C, Pouch	Test 1	Hex[a]	0.013	0.025	0.014	0.043	Y[c]	Y
		Taste[b]	3.81	4.28	3.78	3.57	4.00	Y
	Test 2	Hex[a]	0.030	0.005	0.054	0.074	Y	Y
		Taste[b]	3.83	3.71	4.00	Y	Y	Y

[a] Mean peak area ratio = $\frac{\text{Area of hexanal peak}}{\text{Area of internal std peak}}$
[b] Taste scores as per Kramer and Twigg (1962)
[c] Y = Insufficient samples

Consumer acceptability

Samples of potato dice were tasted by 45 or more untrained tasters to indicate consumer preference. Scores for this test averaged between 6.43 and 7.00 on a 9-point hedonic scale for all samples stored for 12 months. Mean scores for these samples fall in the "like slightly" to "like moderately" range.

High temperature storage

Explosion-puffed low-sugar potatoes stored at 38°C were stable when packaged in a nitrogen atmosphere or in oxygen scavenger pouches (Table 5). Studies involving the use of antioxidants at this temperature were inconclusive and further work is required.

CONCLUSIONS

THE USE OF BHA alone or with BHT is an effective method of retarding the autoxidation of explosion puffed potatoes, keeping oxidative off-flavors below threshold levels for up to 12 months in storage.

The incorporation of a scavenger pouch packaging system, although very effective in its antioxidative effects, was severely limited because of pinhole leaks probably caused by the sharp corners of the dice. A heavier laminate, not tested in these studies, may provide an adequate package for explosion-puffed potato dice.

The use of either of the above methods, when coupled with the use of nitrogen during puffing, resulted in a high quality dehydrated potato product that exhibited a shelf life of at least 1 yr at 23°C.

Table 5—High temperature storage

			Months			
			0	3	6	12
38°C N_2 Can	Test 1	Hex[a]	0.048	0.037	0.051	X[c]
		Taste[b]	3.80	3.76	4.00	4.00
	Test 2	Hex[a]	0.040	0.040	0.033	X
		Taste[b]	3.80	4.13	4.06	3.77
38°C Pouch		Hex[a]	0.022	0.014	0.019	0.028
		Taste[b]	3.62	3.75	3.85	3.75

[a] Mean peak area ratio = $\frac{\text{Area of hexanel peak}}{\text{Area of internal std peak}}$

[b] Taste scores as per Kramer and Twigg (1962)

[c] X = Data not available

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